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A Study on the Differential Response of Malting Barley Genotypes to Boron Toxicity

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ABSTRACT

A field experiment was carried out to study the differential response of eight malting barley genotypes to boron toxicity in Aydın, Turkey. Genotypes were grown with and without the application of 40 kg B ha^{-1}. Total dry matter yield, grain yield and boron concentration of roots, stems, leaves and ears were determined. Boron application resulted in toxicity symptoms at the flag leaves and reduced total dry matter and grain yield as 12.2% and 30.5%. Line 7 gave both the lowest yield reduction and toxicity reading score. In soils both with and without added boron, boron concentrations from the lowest to the highest were determined as ear, stem root and leaf, respectively. When boron was added to the soils, boron concentration of root, stem and leaf were found to be different from each. Applying excess amount of B to the soil resulted in dramatic increases in B concentration of plant parts, demonstrating that cultivars have different abilities to accumulate B if the supply in the soil is too high. In general, line 7 was found as the most tolerant to B toxicity. Another conclusion drown leaf symptom scoring for B tolerance was more reliable than measuring plant boron concentrations.

Key words: Boron, malting barley, genotypes, tolerance

INTRODUCTION

Boron is an essential trace element required for normal growth of plants. But, plants vary in their B requirement. The range between deficient and toxic soil solution concentrations of B is smaller than for any of other nutrient element. In arid and semi-arid areas, B toxicity results from high levels of B in soils and from additions of B via the irrigation water (Marschner, 1995; Nable et al., 1997). Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. For example, there are 20 geotermal areas in The Büyük Menderes River Basin of Turkey (Akar, 2007).

A 17% difference in the grain yield of adjacent areas of barley (cv Clipper) was related to differences in the concentration of boron in shoots just prior to anthesis (Cartwright et al. 1984). Soil amelioration of boron toxicity appears to be impractical. Toxic effects are more marked in dry seasons, when roots penetrate deeper into the soil. Excess B can not be removed from soil or treated in any way under dry-land farming conditions. Therefore, use of tolerant crop varieties is the best option to overcome this problem. Tolerance to B toxicity operates not only at the whole-plant level but also at the organ and cellular level. For example, susceptibility to B toxicity is expressed among barley genotypes at either the whole plant or organ or cellular level (Kalayci et al., 1998; Torun et al., 2003).

Of the plant parameters studied for assessing B-tolerant genotypes controversial results have been reported especially in use of B concentration in plants (Nable et al., 1997) Critical toxic concentrations of B in barley plant tissues were found to vary from approximately 2 to 15 µg/g for grain and from approximately 50 to 420 µg/g for shoot (Riley and Robson, 1994). Shoot reflect well the extent of genotypic variation in barley for tolerance to B toxicity (Nable, 1998). Mahalakshmi et al., 1995 reported that shoot concentration of B is not useful parameter for distinguishing genotypes for their tolerance to B toxicity. There is few published research on malting barley relating with boron. The objectives of this study were to investigate the differential response of eight malting barley genotypes to boron toxicity and B distribution in the plant parts grown in field conditions.

MATERIALS and METHODS

Four malting barley cultivars and 4 advanced lines (Table 1) were grown under rainfed conditions at the Aydın, Turkey in 2004-2005 growing season. Water-extractable B in the 0-30 cm soil was 0.42 mg B kg^{-1}. Other properties of the soil at the 0–30 cm were as follows: soil texture loamy, $CaCO_3$ 25 g kg^{-1}, pH (H_2O) 7.7 and organic matter 12 g kg^{-1}. Plants were grown with 100 kg Borax ha^{-1} (+B) and without (-B) boron applications. Borax containing 11% B was applied onto soil surface and introduced into the soil by disc-plough just before planting.

Table 1. List of genotypes used in the experiment

No	Name	Code of lines
1	Akhisar	
2	Süleyman Bey	
3	Şerife Hanım	
4	Kaya	
5	Line 1	F-10-2001
6	Line 2	MÇTB-2001/177/1
7	Line 3	Arupo/K8755// Mora/3/Cerise/Shyria//Alepo/4…
8	Line 4	MB 2000/13-9

Experimental layout was a split plot design with four replications where main plots were B treatments, and subplots were genotypes. Plot sizes were 6 m^2 (1.2*5 m). Sowing was done in December with a seeding rate of 450 seeds m^{-2}. At planting 60 kg P_2O_5 ha^{-1} and 23 kg N ha^{-1} were applied in the form of diammonium phosphate, and 50 kg N ha^{-1} was top-dressed as ammonium nitrate at the tillering stage in late February. Shoot damage readings were taken using a 1-5 scale (1 = tolerant, 5 = highly sensitive). Boron content was determined after digestion of dried and milled plant material with 6 M H_2SO_4 and H_2O_2 (Wolf, 1982). To determine the B concentrations in the plant parts, the azomethine-H^+ method was followed using spectrophotometry at 410 nm (Wolf, 1974).

RESULTS and DISCUSSION

Boron Reading Score, Shoot Dry Matter and Grain Yield

Malting barley cultivars differed in severity of leaf symptoms of B toxicity when grown in the toxic level B applied. The toxicity symptons, reddish-brown necrotic spots along the margins of flag leaves, became more apparent in the heading stage , being most severe in Akhisar and Şerife Hanım and least severe in Line 3 and Kaya (Table 2).

Shoot dry matter production and grain yield were affected by cultivar and B treatment and there were an interaction between them. Boron application resulted in decreases in shoot dry matter production and grain yield as an average 30% and 8.3%, respectively. The decreases by +B treatment ranged from 1.7% to 38.4% for dry matter yield and from 1.7% to 25.3% for grain yield. Interestingly line 3 gave the highest dry matter production and grain yield when grown in +B. When the response of individual genotypes studied, genotypes behaving similarly in both shoot dry matter and grain yields were found. In case of grain yield, Line 3 was superior genotype in both –B and +B conditions. The results in Table 2 indicate that line 3 and Line 1 seem to be more tolerant to B toxicity while Akhisar is highly susceptible. These results were similar to Torun et al. (2003) and Rehman et al. (2006) who studied genotypic variation in tolerance to B toxicity.

Table 2. The effect of B application on the B reading score, shoot dry matter and grain yield of malting barley cultivars

Genotypes	Leaf symptom scores +B	Shoot dry matter (kg ha^{-1})			Grain yield (kg ha^{-1})		
		-B	+B	Decreases (%)	-B	+B	Decreases (%)
Akhisar	4.1a	5417a	3409c	37.1	3300b	2732bc	17.2
Süleyman Bey	3.7ab	5778a	3937b	31.9	3900a	3502a	10.2
Şerife Hanım	3.5b	5752a	3543bc	38.4	3420b	2940b	14.0
Kaya	2.9c	4333c	3632b	16.2	2975d	2223c	25.3
Line 1	3.3bc	4889b	4396c	10.1	3850a	3625a	5.8
Line 2	3.1bc	5000b	4048ab	19.0	2503c	2339c	6.6
Line 3	1.0d	4500c	4425a	1.7	4000a	3932a	1.7
Line 4	3.6ab	5000b	3923b	21.5	3060b	2782bc	9.1
Average		5376	3733	30.0	3493	3218	8.3
Genotypes (G)	**		**			*	
Boron (B)			*			**	
(GxB) int.			**			*	

Boron Concentrations of Roots, Stems, Flag Leaf and Grain

Boron concentration in the root at harvest was affected by cultivar and B treatment (P<0.01). In treatment –B, there were no significant differences among the cultivars and their B the concentrations ranged from 20 to 26 mg B kg^{-1}. In treatment +B, the differences were much greater (75-113 mg B kg^{-1}), demonstrating that cultivars have different abilities to accumulate to accumulate B if the supply in the soil is too high. Increases in B concentrations was maximum for Süleyman Bey and minimum for line 3 (Table 3). Root B concentrations in -B and +B were similar with the nutrient solution experiment reported by Kalayci et. al., 1998.

Boron concentration in the stem at harvest was affected by cultivar and B treatments (P<0.01). In treatment –B, the range of the concentrations were too small (5.46-6.56 mg B kg^{-1}). In treatment +B, the differences were much greater (16.5-36.4 mg B kg^{-1}). Increases in B concentrations was maximum for Süleyman Bey and minimum for Kaya (Table 3).

Table 3. The effect of B application on the boron concentrations of roots and stems

Genotypes	Root			Stem		
	-B	+B	Increases (%)	-B	+B	Increases (%)
Akhisar	20a	108a	433	6.24a	36.4a	483
Süleyman Bey	20a	113a	459	5.46a	16.5c	202
Şerife Hanım	21a	112a	449	6.51a	26.4b	306
Kaya	25a	87bc	243	6.22a	17.9c	187
Line 1	19a	75c	298	6.17a	30.5ab	394
Line 2	20a	95b	368	5.67a	22.6b	299
Line 3	26a	105a	297	5.63a	32.3ab	474
Line 4	22a	106a	372	6.56a	27.1b	313
Genotypes (G)	**			**		
Boron (B)	**			**		
(GxB) int.	**			**		

Boron concentration in the flag leaf at harvest was affected by cultivar and B treatment (P<0.01). In treatment –B, there were no significant differences amongst cultivars although the concentrations ranged from 24 to 30 mg B kg^{-1}. In treatment +B, the differences were much greater 69-144 mg B kg^{-1}. Increases in B concentrations was maximum for Akhisar and minimum for line Line 3 (Table 4). Nable et al. (1997) reported that shoot growth is reduced when shoot B concentrations are excess of 120 mg kg^{-1} dry weight. In pot experiment critical toxicity concentrations of B in barley shoot varied between 40 and 150 mg kg^{-1} dry weight (Riley et al., 1994).

Boron concentration in the grain was affected by cultivar and B treatment ($P<0.01$). In treatment –B, there were no significant differences amongst cultivars although the concentrations ranged from 2.45 to 3.12 mg B kg^{-1}. In treatment B^{+}, the differences were much greater 11.1-18.5 mg B kg^{-1}. Increases in B concentrations was maximum for Akhisar and minimum for Line 3 (Table 4). Critical toxic concentrations of B in barley grain were found to vary from approximately 2 to 15 µg g^{-1} (Riley and Robson, 1994) which was similar with +B treatment of present experiment.

Table 4. The effect of B application on the boron concentrations of flag leaf and grain

Genotypes	Flag leaf			Grain		
	-B	+B	Increases (%)	-B	+B	Increases (%)
Akhisar	25a	182a	617	2.50a	18.5a	640
Süleyman Bey	24a	116b	378	2.73a	14.7b	439
Şerife Hanım	24a	106c	336	2.45a	13.4b	447
Kaya	26a	94cb	267	2.64a	11.1c	319
Line 1	28a	83c	201	3.12a	16.5ab	428
Line 2	25a	124b	397	2.94a	15.7b	435
Line 3.	30a	69c	133	3.02a	11.3bc	275
Line 4	29a	144b	401	2.53a	12.3bc	388
Genotypes (G)		**			*	
Boron (B)		**			*	
(GxB) int.		**			*	

Boron concentrations of in the analyzed plant parts were not differed among the cultivars in control treatment. Applying excess amount of B to the soil resulted in dramatic increases in B concentration of plant parts, demonstrating that cultivars have different abilities to accumulate to accumulate B if the supply in the soil is too high. In general, these increases were maximum for Line 3 (in leaf and grain) and Kaya (in root and stem) and maximum for Akhisar.

Correlation coefficients between dry matter yield reductions (%) by +B and different parameters were presented in Table 5. Flag leaf symptom scores, flag leaf B concentration in -B and +B gave the highest correlation with dry matter yield reductions (%) by +B as correlation coefficient of 0.797*, -0.745* and 0.689*, respectively. Low the dry matter reduction (%) by +B could be attributed to the lower toxicity symptoms score of leaf blade and the lower flag leaf B concentration in +B and the higher flag leaf B concentration in -B. Similar results were reported by Kalayci et al., (1998) who also concluded that leaf symptom scoring to B tolerance was more reliable than measuring plant boron concentrations. Jenkin (1993) assessed differences in both grain yield and leaf symptoms in three populations derived from crosses between tolerant and intolerant parents grown on soil high in boron concentration and yet found no consistent relationship between leaf-symptom expression and grain-yield response.

The results presented here indicate that among the genotypes line 7 is the most tolerant to B toxicity. Further researches should be carried with Line 7. Leaf symptom scoring for B tolerance is more reliable than measuring plant boron concentrations.

Table 5. Correlation with dry matter yield reductions (%) by B^+ and different parameters

	Correlation coefficient	
Parameters	-B	+B
Root B concentration	-0,537ns	+0,604
Stem B concentration	0.304ns	-0,087ns
Flag leaf B concentration	-0,745*	0,689*
Grain B concentration	0.303ns	-0.087ns
Flag leaf symptom scores		0.797*

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